DOCUMENT RESUME

ED 178 265 SE 027 859

AUTHOR Shulman, Lee S.; Tamir, Pinchas
TITLE Science and Mathematics Education: Retrospect and Prospect. Occasional Paper No. 11.
INSTITUTION Michigan State Univ., East Lansing. Inst. for Research on Teaching.
SPONS AGENCY National Inst. of Education (DHEW) Washington, D.C. Teaching Div.
PUB DATE Dec 7?
CONTRACT 400-76-0073
NOTE 38p.; Paper presented at the Anniversary Conference of the Science and Mathematics Teaching Center, Michigan State University (20th, East Lansing, May, 1977); Contains light and broken type
AVAILABLE FROM Institute for Research on Teaching, 252 Erickson Hall, Michigan State University, East Lansing, Michigan 48824 ($2.00)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Development; Curriculum; Elementary Secondary Education; *Evaluation; Higher Education; Inservice Teacher Education; Learning Theories; Objectives; *Preservice Education; Science Course Improvement Project; *Science Education
IDENTIFIERS Piaget (Jean)

ABSTRACT

Changes in science education are examined and speculations made on what these changes imply for the future. Among the topics included are science subject matter, the learner and learning, curriculum development, science as inquiry, the laboratory, Piaget and science education, evaluation and teacher education. (PB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

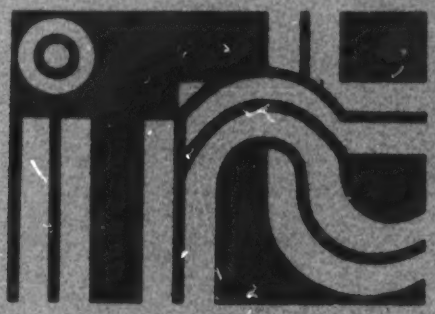
U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Pinchas Tamir

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ED178265



Institute for Research on Teaching

College of Education — Michigan State University

SE 027 859

$2.00

Occasional Paper No. 11

SCIENCE AND MATHEMATICS EDUCATION: RETROSPECT AND PROSPECT

Lee S. Shulman and Pinchas Tamir

Published By

The Institute for Research on Teaching
252 Erickson Hall
Michigan State University
East Lansing, Michigan 48824

Printed and Distributed
by the
College of Education
Michigan State University

December 1978

The Institute for Research on Teaching is funded primarily by the Teaching Division of the National Institute of Education, United States Department of Health, Education, and Welfare. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the National Institute of Education. (Contract No. 400-76-0073)

Institute for Research on Teaching

Teachers' thoughts and decisions are the focus of studies currently under way at Michigan State University's Institute for Research on Teaching (IRT). The IRT, founded in April 1976 with a $3.6 million grant from the National Institute of Education, has major projects investigating teacher decision-making, including studies of reading diagnosis and remediation, classroom management strategies, instruction in the areas of language arts, reading, and mathematics, teacher education, teacher planning, effects of external pressures on teachers' decision, and teachers' perceptions of student affect. Researchers from many different disciplines cooperate in IRT research. In addition, public school teachers work at IRT as half-time collaborators in research, helping to design and plan studies, collect data, and analyze results. The Institute publishes research reports, conference proceedings, occasional papers, and a free quarterly newsletter for practitioners. For more information or to be placed on the IRT mailing list please write to: The IRT Editor, 252 Erickson, MSU, East Lansing, Michigan 48824.

Director: Lee S. Shulman

Associate Director: Judith E. Lanier

Editorial Staff:

Lawrence W. Lezotte, coordinator of Communications/Dissemination
Linda Shalaway, IRT editor
James Kern, editorial assistant
Janice Behrs, editorial assistant

Science and Mathematics Education: Retrospect and Prospect[1]

Lee S. Shulman and Pinchas Tamir[2]

An examination of the past and the future of science and mathematics education reveals a startling paradox.

On the one hand, there has rarely been a time when the importance of science education and scientific and mathematical literacy among the general population has been easier to demonstrate. President Carter's first trip to Europe, for example, was dominated by discussions, neither of alliances nor economics, but of energy and nuclear proliferation; correspondents for the television networks attempted desperately to explain the problems of breeder reactors to the American public. Elections in our decade are won or lost, especially in the western states, on the candidates' positions with regard to ecology, environment, and energy issues. More recently, we have seen debates on the safety of basic research in genetics move from scientific assemblies to legislative assemblies such as the city councils of Cambridge, Massachusetts, and Ann Arbor, Michigan. City councilmen not specifically trained in science now argue about potential mutations in a tiny organism called *E. Coli*, a permanent resident of human intestinal tracts, and about whether to permit recombinant DNA research in their localities. These council-

---

[1]Prepared for the Twentieth Anniversary Conference of the Science and Mathematics Teaching Center, Michigan State University, May 1977. Published in R. Brandenburg & J.J. Gallagher (Eds.), Proceedings of the Conference Marking the 20th Anniversary of the Science and Mathematics Teaching Center, East Lansing, MI: Michigan State University, 1977. (forthcoming ERIC Document)

[2]Lee S. Shulman is director of the Institute for Research on Teaching and a professor of educational psychology and medical education. Pinchas Tamir is associate professor of science education in the Israel Science Teaching Center of the Hebrew University of Jerusalem.

men may have as much to say about the future of investigations in this frontier of molecular biology as does the National Academy of Sciences.

Yet, despite such indications of the need for scientific literacy, no public clamor for increased emphasis on science and mathematics education is apparent. The cries of "back to basics" rarely include science, and stress computation, not mathematics. Thus we find ourselves in 1977 confronted with this paradox: We, the American public, need to know more science in order to live in and run our society, but we appear unwilling to invest the time, energy, and the activities of our teachers and students to the pursuit of excellence and understanding in the science and mathematics fields.

It was with this paradox in mind that we approached this very general review of the science and mathematics teaching fields over the past 20 years, since the creation of the Science and Mathematics Teaching Center in 1957. We focused especially on the seven years since our last joint review (Shulman & Tamir, 1973).

The year 1957 was a very interesting one. It marked in many ways, the dawn of several revolutions. Although there were earlier math education developments, 1957 signaled the birth of the curriculum development revolution in this country. That revolution can be examined in terms of the four commonplaces of education that Joseph Schwab, a distinguished science educator, elaborated in his Inglis Lectures on the teaching of science as inquiry (Schwab, 1962): the *subject matter* or *curriculum*; the *learner* and the processes of learning; the *teacher* and the processes of teaching; and the *milieu* or the context.

Subject Matter

The revolution in curriculum development rapidly brought subject

matter specialists into the field of science education. People like Zacharias, Begle, Karplus, Davis, Schwab, and Holton, who were leaders in the disciplines, became senior partners overnight in the process of curriculum development in mathematics and the sciences. Bridgham (1969), in an insightful paper, anticipated one of the problems that was to arise because of this new partnership; namely, scientists and mathematicians entering the curriculum development arena often brought with them conceptions of science and mathematics which were not totally clarified before being translated into curriculum materials. All educators felt some of the consequences of that ambiguity in the ensuing years as they attempted to deal with these curricula.

The Learner and Learning

The year 1957 also signaled the movement of another group into the science and mathematics education fields -- the psychologists. They came along with the subject matter specialists and introduced a decade of discovery learning, inquiry, higher order cognitive processes, task analysis, and individualization. By and large, these were psychologists who had never before worked on classroom instruction. The group included Piaget, who did not work personally on the new curricula but whose name was always invoked with great solemnity in the defense of almost anything; Barbel Inhelder, his collaborator; Jerome Bruner; Robert Gagne; David Ausubel; and many others.

The psychologists brought about two major developments: (1) they helped emphasize the cognitive processes central to school learning (as evidenced by the centrality of discovery and inquiry in many of the new curricula), and (2) they heightened interest in individual differences among students (especially differences in learning rate or aptitude) and the need to develop programs or curricula that could be adapted to those

differences. Educators and curriculum developers thus began generating a series of programs, some of which were oriented toward the cognitive and discovery processes,[3] and others which developed a bit later that were oriented toward the individualization of instruction.[4]

Due to a remarkable coincidence of timing, 1957 not only marked the beginning of the curriculum revolution, but the beginning of a revolution in the field of psychology as well. Indeed, 1957 was an incredible year for psychology. Within 12 months of the creation of the Science and Mathematics Teaching Center, the following developments occurred in the field of psychology:

1. Bruner, Goodnow, and Austin's *A Study of Thinking*, was published (1956). One of the first and (still) most influential books on the experimental study of concept learning, it used that word "thinking," which had been considered almost obscene in psychology since the death of the Würzberg school some 50 years earlier.

2. George Miller (1956) wrote a paper on "the magic number 7 plus or minus 2" that signaled an interest on the part of psychologists in problems of memory capacity, especially short-term memory, and heralded the beginning of information-processing psychology.

3. Newell, Shaw, and Simon (1958) conducted research on the use of information-processing models in proving mathematical theorems. Their work served as the basis for almost all information-processing psychological research in education to date.

---

[3] For example, the Elementary School Science (ESS), Biological Science Curriculum Study (BSCS), Physical Science Study Committee (PSSC), Science Curriculum Improvement Study (SCIS).

[4] E.g., Individually Prescribed Instruction (IPI), Individually Guided Education (IGE), Individualized Science Improvement Study (ISIS).

4. An obscure young linguist at Massachusetts Institute of Technology, Noam Chomsky (1956), published *Syntactic Structures*, which has rendered almost obsolete what was then the mainstream of experimental psychology.

A few years later, Miller, Galanter, and Pribram (1960) collaborated on *Plans and the Structure of Behavior*, which attempted to summarize and coordinate into a single theoretical model work on computer-based information-processing models and developments in transformational grammars.

Bruner brought psychologists together with a group of subject matter specialists at the Woods Hole Conference and then wrote *Process of Education* (Bruner, 1960), based loosely on the deliberations of the conferees. Barbel Inhelder contributed to the book an entire chapter on her work with Piaget, whose perspective had not previously been central to curriculum development.

Within a year, J. McVicker Hunt (1961) published *Intelligence and Experience*, which attempted to demonstrate -- and in many ways did so convincingly -- that one could take the information-processing model on one hand and the cognitive developmental model of Piaget on the other, combine them, and have a meaningful theory of intelligence.

The coalition between the psychologists and the subject matter specialists was an interesting one. Robert Davis (Note 1) has observed that there was an unstated agreement between the groups that the psychologists would defer entirely to the subject matter specialists with respect to judgments about what was worth teaching. Even when the topics that the subject matter specialists insisted upon struck the psychologists as inappropriate, Davis claims, the psychologists remained silent. On the other hand, the subject matter specialists deferred entirely to the psychologists with respect to the question of "How do you get this stuff

into the heads of the students?" Davis uses a pipeline metaphor to characterize the working relationship: The subject matter specialists, he says, decided what went into the pipe and the psychologists constructed the conduit for getting it into the curriculum. (Teachers and science educators were those at the other end of the pipeline, who translated the curriculum materials into operational programs.) In many ways educators may have paid a price for this arrangement; the two groups respected each other's turf much too seriously, when both had sufficient good judgment to raise germane questions about the other's work.

There was yet another irony in this psychologist-subject matter specialist coalition. Most of curriculum development, funded primarily by the National Science Foundation (NSF), had a strong cognitive discovery orientation and, by law, required evaluation. Though not an unreasonable requirement in principle, it became ludicrous in practice. The evaluation models regnant in the 60s derived from a corner of psychology and education totally different from the cognitive models underlying the new curricula. Thus a set of curricula rooted in theories of cognitive development, cognitive learning, discovery, and inquiry in students was being evaluated with an evaluation technology characterized by the performance objectives and task analysis of neo-behaviorism. By and large, the evaluations indicated that the new curricula were only equivocal in impact. But that may well have been due to the mismatch between the ideology that produced the curricula and that which directed the evaluations.

Milieu

The sudden clamor, after Sputnik, for the creation of a new elite of scientists and engineers to compete with the Russians was the source of much new curriculum development. In many ways, however, there was a

misreading of the milieu. Curricula developed on the assumption that the social needs of the time were stable and unchanging. A few years later, in the late 60s and early 70s, high school and university students shocked educators into recognizing that this assumption was wrong. Indeed, in 1971, Bruner partially recanted and apologized for having failed to realize that this society -- the political and social context in which education exists -- was unlikely to remain stable.

Members of the mathematics and science teaching community began to observe reactions to the elitism of the earliest of the new curricula, reactions epitomized, perhaps, by the response to the Physical Science Study Committee embodied in Harvard Project Physics. Later, a variety of new programs reflecting a growing concern for the needs of the society emerged. Several different, but related, features characterized these new programs: (1) integrated, interdisciplinary approaches with a focus on social and environmental issues; (2) greater emphasis on attitudes and values as related to science; (3) courses dealing with applied aspects of science, with a growing recognition that although technology is not science, it is closely related to science and deserves appropriate treatment in the context of learning science; and (4) special efforts to meet the needs of minorities and disadvantaged students.

The Teacher

Interestingly, while modes of teaching received a great deal of attention from those who developed the curricula -- with emphasis on the laboratory, student experiments, "invitations to enquiry," individualized instruction, and a variety of technologies -- the person responsible for operating this "subject matter-technology-individual student" complex -- the teacher -- received little attention. We made much of the fact that our NSF workshops brought teachers to our campuses every summer. And to be sure,

for the teachers involved, the workshops were an exciting experience; contributions were made which helped teachers make their programs more realistic, more understandable, and more successful. By and large, however, the central role of the teacher to the program, and the importance of continuous teacher support, was at the bottom of the priority list. Indeed, the chapter we wrote in 1970 on "Research on Teaching in the Natural Sciences" (Shulman & Tamir, 1973), contains few references to the study of teaching and teachers.

There seemed to be a feeling among curriculum developers and educators that if they could get a curriculum into shape, package it well, and find the right technologies for the laboratories and individualization, teaching would take care of itself. They have learned differently. In fact, questions of teachers and teaching, though much ignored in the history of science education, are central to the future of the field. The teacher is the key to the adaptation and implementation of existing curricula. Passow (1976), in discussing the future of secondary education, argues that society, itself, must serve as the core of the curriculum; yet he is quick to admit that, with whatever changes we hope to make, we must recognize the supreme importance of those working at the "grass roots" in effecting change.

Prospects for Science Education

We would like to review some of the changes we would make if we were to re-write our chapter (Shulman & Tamir, 1973) on the teaching of natural science today. We shall point out some of the ways in which the field of science education has changed over the last seven years and what these changes seem to suggest for the future.

Curriculum Development

Funding for curriculum development at the national level is finished. An era is over, for a number of reasons.

First, the era ended because the development effort did not accomplish what it was expected to accomplish. It did not revolutionize life in classrooms. Somehow, when the new curricula reached the classroom, they did not iulfill the dreams shared by teachers, scientists, mathematicians, teacher educators, and curriculum specialists, when they created those beautiful programs.

Another reason for the end of the era is that, for now, educators are inundated with curricula. There are more curriculum materials, modules, packages, and kits than any single school system could possibly incorporate. For the moment, then, investment in large-scale national curricula is not in order. Moreover, studies of curriculum implementation have made it clear that the key to successful curriculum development and application is an understanding of how curricula can be adapted to local conditions. Adaptation will occur whether or not it is planned -- so it had better be anticipated. This is one of the exciting new developments in the field of science and mathematics education, a shift of focus away from centrally organized curriculum development and toward curriculum use, adaptation, and implementation.

It is not surprising that most of the research on implementing curricula at the local level has been conducted in countries such as Israel, Mexico, England, and France, where it was recognized that educators could not take a BSCS, an SCIS, or a *Sesame Street* and merely translate it for instant use in other countries. Foreign educators realized that they first had to make modifications. For this, they needed guidelines, conceptual models, schemes for decision making,

and technologies for analyzing programs and identifying their important features; and then those guidelines, models, schemes, and technologies had to be translated into materials that were appropriate for local conditions, national needs and interests, learner characteristics, the particular structure of the curriculum in which they were to be embedded, and the like. Three schemes for curriculum analysis of this kind have recently been developed by Allen (Note 2), Blum (Note 3), and Ben-Peretz (Note 4). The scheme developed by Blum has been used in the exchange of science programs between Hawaii and Israel.

Kilpatrick (Note 5) has reported on the concept of curriculum "half products" devised by Limmee. Under this concept, curriculum developers are encouraged to develop incomplete curricula, which cannot be mindlessly incorporated or assimilated into a program (even if teachers want to incorporate them). The incomplete curricula are almost like those records which allow one to play a Beethoven piano concerto along with the Philadelphia Symphony Orchestra; if the piano is not played, the concerto is heard without a piano, which is far from satisfying. The curriculum half-products are created fully enough that teachers can complete them by working on them and manipulating them; but they must do that before the materials are ready for use. We find this a fascinating idea in curriculum development. Like other new ideas, it needs to be investigated further. Among the questions that need to be answered are: (1) How can teachers complete the materials? (2) How *do* they complete the materials? and (3) How can they be *trained* to complete the materials?

We are beginning to see research on the adaptation of curricula emerging at Michigan State University's Science and Math Teaching Center. Smith (Note 6) is studying science teachers as they plan units of instruction that frequently require the adaptation of curriculum materials. Shroyer's

(Note 7) studies of mathematics teachers are similar. Much of our work in the Institute for Research on Teaching deals with teacher planning in reading, the language arts, mathematics, and general classroom management (Shulman & Lanier, 1977). We predict that in our field of science and math education, curriculum research will experience a renaissance, this time at the level of the interface between the materials and instruction; that is, we see emerging studies of teacher planning and teacher development of instruction, using as sources the many kinds of material available and then adapting them to fit the teacher's assessment of the learners' characteristics, community interests, and needs of the overall general curriculum of the school.

Science as Inquiry and Teaching by Inquiry

An important issue in the area of curriculum development -- and a source of continuing confusion, as we see it -- is the distinction between teaching science as inquiry and teaching *by* inquiry. This is an issue Shulman and Kiesler (1966) struggled with in the *Learning by Discovery* volume 11 years ago. We addressed it subsequently (Shulman & Tamir, 1973) and as far as we can tell it is worth reiterating today since there remains a confusion about the two concepts. As emphasized by Schwab (1962):

> The phrase the teaching of science as enquiry is ambiguous. It means, first, a process of teaching and learning which is, itself, an enquiry, "*teaching* as enquiry." It means, second, instruction in which science is seen as a process of enquiry, "science as enquiry." Both of these are parts of the idea in its complete form. . . . Of the two components -- science as enquiry and the activity of enquiring -- it is the former which should be given first priority as the objective of science teaching in the secondary schools. (pp. 65, 71)

Unfortunately, although 15 years have passed since this distinction was made, there is still a tendency to equate "teaching by inquiry" with filling the science curriculum with activities that look like inquiries. One of the consequences of this line of reasoning has been the continued misuse of

what is probably the hallmark of science education, the laboratory.

The Laboratory

In our earlier chapter (Shulman & Tamir, 1973) we cited the work of Schwab (1962) and Herron (1971), among others, to indicate that there is a "rhetoric of inquiry" in science education which strongly encourages teachers and curriculum makers to teach students to solve problems and think. Ostensibly, the laboratory was set up as the vehicle for teaching problem solving under the new curricula, such as BSCS and PSSC. However, in the overwhelming proportion of the labs that were established, students were provided with a definition of a problem, told the set of procedures to employ, and frequently given the key against which to check their answers. Some inquiry! We fear that much of this kind of "inquiry" continues to occur, although the direction of recent research on the science laboratory may provide the guidance needed to redress the problem.

More precise and careful studies of learning in the science laboratory are being pursued. Finer grained analyses of the kinds of learning to be undertaken and of the kinds of instruction that are, in fact, provided are being conducted (Tamir, 1977). There are also studies focusing on specific issues, such as the extent to which the nature of directions guides and influences student observation in laboratories (Kempa & Ward, 1975) and the cognitive and affective outcomes of substituting filmed experiments for actual laboratory work (Ben Zvi, Hofstein, Samuel, & Kempa, 1976a and 1976b).

We find (and this seems a most important observation) that one of the ingredients necessary to transform laboratories from parodies of inquiry, where students simply go through the motions and the imitation of science, to *bona fide* inquiry, is the pre-lab and post-lab discussion (Tamir, 1977). It has become very clear that active manipulative

laboratory work may achieve its promise as true inquiry only when it is followed by active discussion. As Woodworth and Dewey and others pointed out many years ago, people learn not by just doing, but by thinking about what they are doing. Inquiry in science and mathematics is no exception; it cannot be achieved merely by doing, and the "thinking about what we are doing" must in most cases be teacher-directed in a small or large group setting. An important advance in this respect is the development of materials for teaching science by inquiry through discussion of original research papers (Connolly, Feingold, & Walshtrom, Note 12).

Discussion is important not only for laboratory work, but also for work done by individual students. So much of that work is never consolidated, never brought together, never elaborated, and never related to anything else.

Individualized Instruction

Individualization remains one of the major trends in American education. As mentioned before, programs like IPI, ISIS, and IGE, at the precollege level, and PSI (Personalized Systems of Instruction), at the college level, have by and large taken over many science courses. For the same reasons that we advocated caution about group laboratory work that is not followed by discussion, consolidation, and critical examination, we suggest that caution must be exercised with individualized instruction. Research at the Open University in England (a university of 50,000 students in which instruction is given by correspondence and television) has repeatedly indicated that most students pass their individual unit diagnostic tests, but when they sit for the final exam, 50% of them fail (McIntosh, Note 13); they have learned the pieces but have never had an opportunity to put them all together. A fascinating series of case

studies at the University of Illinois on the learning of mathematics in an IPI curriculum yielded similar findings (Erlwanger, 1975). In the studies, several students who ranked in the top 25% of their class and who had successfully passed one unit test after another were interviewed clinically to probe what they really understood. Some were found to have developed weirdly idiosyncratic algorithms for passing the tests; they had simply developed ad hoc, inconsistent, and inaccurate mathematical theories and rules which somehow got them through the units, but which led to a totally distorted understanding of mathematics. Apparently, the nature of the individualized program in question (and this may well be true of almost all individualized curricula) is such that if pupils score well on unit post-tests, they rarely talk to anybody about it. The teacher doesn't talk to them. The aide, who typically scores these tests, doesn't talk to them. It seems that if there are errors, the students pick up cues from the aide to see what the right answer would be, then run back and redo the post-test.

The results of Erlwanger's research are frightening, because they again highlight a perplexing dilemma: Although individualization has solved some problems in science and mathematics instruction, it has created (unintentionally but quite predictably) a new set of problems that may, in the long run, be more serious than the problems it was supposed to solve. Clearly, some sort of proper blend is needed; educators need not forego the fruits of individualization, but they cannot countenance the bitter fruits among them. Teachers must learn both to employ the techniques of individualized instruction and to return to teaching. They must return to active interaction with groups of students by discussing with them the materials of instruction, taking responsibility for explaining, coordinating, and consolidating the knowledge that students acquire within

the laboratory or the individualized carrel. This recommendation, of course, places great responsibility on teacher educators to prepare teachers to accomplish this very difficult task.

Piaget and Science Education

An examination of the presentations made at the latest meeting of the National Association of Research in Science Teaching (NARST) shows that Piaget and Piagetian studies continue to dominate research on learning in science and mathematics. We find three types of investigation: (1) attempts to replicate Piaget's studies with new samples or new tasks and to develop new measures for locating individuals at particular developmental levels; (2) attempts to demonstrate (in the form of training experiments) acceleration of transition from lower to higher stages; and (3) attempts to use Piaget's concepts or methods to anticipate cognitive difficulties students may encounter in learning concepts in science or mathematics.

We would like to indicate, as we have in other places, that those Piagetian studies included under categories (1) and (2) are, in our opinion, irrelevant to science education. The irony is that Piaget's clinical method originated as an alternative to the mindless use of the quantitative - experimental paradigm in research on instruction, which may be described as: "Grab two groups, do something to one of them, lock up the other, run your ANOVA and . . ." What seems to have occurred since is a similar misuse of the Piagetian paradigm. Instead of "grab two groups," it is now "find three kids, one of each age."

This approach is unproductive for several reasons, the primary one being that the problems of science education are different from the problems addressed by Piaget. Most of Piaget's work is focused on the problem of *vertical decalage*, of mapping developmental stages over time, longitudinally, as the child grows. The goal of science education is *not* to move children ahead to

concrete operations. (They are going to get there anyway.) The major problems of science education are those of *horizontal decalage*, of enriching and differentiating student understanding within a level of development. Piaget has little to say about that, not because he is a bad psychologist, but simply because that is not his problem. Yet investigators have latched onto Piaget's methods and his research paradigm, and for 15 years have been overusing it with science and mathematics research.

As Doyle and Lunetta (1977) suggest, science educators should view Piaget in perspective. While we feel that no more studies in categories (1) and (2) are necessary, we welcome studies of category (3) which deal with concepts of science and mathematics that are intrinsically important to those developing science and math curricula. Studies of this kind begin with fine-grained analyses of the concepts in question and of the conditions for their development. Then, examinations are conducted on instruction in the science and math fields (Smith,Note 14). It is important to note that the concepts under study are *not* chosen merely because Piaget or his disciples judged them important; they are chosen because the researcher considers them central to the teaching of science and mathematics. A recent study by Nussbaum and Novak (1976) on the development of the concept of the Earth in young children provides a good example of this approach. Certainly, it is hard to think of an elementary science curriculum which will not deal with the concept of Earth at some point. Children are asking about it all the time. But despite its obvious educational relevance, the concept has no intrinsic importance to cognitive developmental psychologists. They are concerned with, and could make use of, a concept like conservation, but conservation is not of any particular intrinsic importance to science education. (It might have some relevance,

but not as much as one would infer from the quantities of information on water-pouring that appear in the research literature on science and mathematics teaching.) As observed by Klausmeier (1977):

> Children appear to acquire concepts and other outcomes in the cognitive domain gradually, rather than abruptly, although qualitatively different cognitive operations are presumed to emerge which make possible successively higher levels of concept attainment. . . . Focused instruction clearly aids students to attain concepts to successively higher levels during short time intervals and also to use their concepts in understanding principles and in solving problems . . . . The quality of educational experience exerts a strong influence on both the rate and the final level of cognitive development. (p. 179)

Evaluation

In the past seven years we have witnessed two trends working in opposite directions. On one hand, we observe a growing emphasis on accountability, which requires more testing and more evaluation. On the other hand, we perceive a growing distrust among educators of the various forms of assessment carried out in schools. These assessments, which rely heavily on paper and pencil standardized tests, are considered to be unidimensional and simple-minded and, hence, incapable of measuring what competent educators are trying to achieve in science and mathematics teaching. While we agree that new approaches to evaluation are badly needed, we would like to point out that a number have already been developed (see Shulman & Tamir, 1973; Educational Development Center, 1976; McGuire, 1976). It seems possible, therefore, to design evaluation systems which will provide the information demanded by those who seek accountability, but will at the same time effectively evaluate learning and instruction.

The Israeli matriculation examination in biology is an example of such a system. All twelfth-grade students in Israel take the national matriculation examinations at the end of their high school studies. These examinations are similar to the O and A level examinations given in England,

and a certain minimum score across a certain number of subjects is a prerequisite for university admission. At one time, the biology exam was quite similar to European matriculation tests; it was a test of knowledge -- a lot of knowledge. When the Israeli adaptation of the BSCS was introduced in Israel, however, educators realized that an alternative form of the exam should be developed for BSCS students. They also came to recognize that the exam was not merely a test of achievement, but potentially the most powerful form of influence on curriculum.

Today, all exam items and practical exercises are published and made available to the teachers, who soon realize that it is not so bad to teach for the test. Both teachers and students know what the test is like, and they find that the best way to prepare for it is to teach or study biology as inquiry, to solve problems in the laboratory, to analyze research papers, etc. (Tamir, 1976). In this manner, the accountability system is reconciled with the instructional program. Our message is clear: Teachers must somehow gain control of either the assessment program or alternatives within the assessment programs. They should not fight accountability -- we all are accountable and *should* be. But they should not allow themselves to be held accountable for things they neither teach nor intend to teach.

Accountability programs, it should be noted, can work in favor of curriculum innovations and affect the form a curriculum takes. Among the most striking findings of a recent comparative study of the formal and non-formal education systems in England (Bennett, 1976) was that while formal education (as there defined) led to higher average academic achievement in traditional senses, the schools that had maintained the 11-plus exam, whether formal or non-formal in their orientation, demonstrated more

measurable achievement than those that did not. Apparently, then, the externally-mandated assessment had more influence on what teachers taught (and students learned) than did their decisions to teach in a formal or non-formal manner.

Teacher Education

The preparation of teachers will grow in importance in the coming years; we have laid out the argument for that point already. We are beginning to see the development around the world of teacher education materials designed specifically for preparing science teachers. We can find the STEP (Science Teacher Education Program) in England, the ISTEP program in Israel, the ASTEP in Australia, and the UPSTEP in Iowa. The development of these programs is consistent with the general trend toward recognizing that teaching is subject-matter specific rather than generic across subject areas. In addition, these four programs reflect a growing recognition that teachers must be trained to balance curriculum alternatives packaged in central development agencies with what is dictated by conditions in the classroom. The concept of half-product curriculum units will fit well into these programs.

In general, teacher educators will not be able to train teachers by admonition or by theory alone to engage in curricular synthesis and development. Rather, they must conduct systematic studies of the methods used by teachers who are effective in planning and executing curriculum adaptations and then train others on the basis of what they find. By and large this training will be done more with teachers already in the field than with preservice teachers -- in part, because many in service teachers will be teaching for a long time to come, and in part because it is very difficult to teach someone with only preservice teaching experience how to

adapt curriculum to the exigencies of the classroom. Training of this kind might be made a continuing in-service professional development activity. We can already find models of this kind of work in the Science and Math Teaching Center (McLeod, Note 15).

The Future

What does the future hold for science and math teaching?

We regret that we must conclude on a pessimistic note, with a word of caution and warning. If the signs we see are accurate, problems lie ahead, especially for the field of science education.

In recent years we have witnessed an increasing demand for education in "the basics." Most teachers and administrators will probably interpret that as a demand for more instructional time on language acquisition, reading, writing, and basic arithmetic calculation skills at the expense of "less essential" areas, such as science and the social studies. There is a real danger that many of the efforts made in the 1960s to improve and enrich science education will be wasted simply because less science will be taught in the elementary schools.

The increasingly frequent research findings documenting what appears to be a direct relationship between engaged learning time and academic achievement (e.g., Bloom, 1976; Harnischfeger & Wiley, 1976; Rosenshine & Berliner, Note 16) will exacerbate the trend. When students fail to "master" some basic skill, the time for remediation and relearning must perforce be taken from a "less basic" subject.

It is therefore highly important that educators and the public be made aware of the qualities of science instruction as a means for developing basic skills, both in language and in arithmetic. A number of studies have pointed toward the potential of science for the teaching

of language, reading, and writing. Rowe (1970) found that the amount of student-initiated, content-relevant speech in 10 Harlem classrooms was 200-to-500% higher during science classes than during language arts classes. Similarly, McGlathery (1968), Ayres and Mason (1969), Huff and Languis (1973), and Renner and Coulter (1976) all found that young children involved in activity-based science courses made considerable language gains. Quinn and Kessler (Note 17) found that as children improved in creating and formulating hypotheses, their language became syntactically more complex, and that this happened without any direct effort to teach language. Thus there appears to be a cognitive link between the ability to make scientific hypotheses and language development.[5]

An entirely different kind of relationship is perceived by Thier (1976), who writes:

> To read successfully the child must be able to discriminate between words that are alike and words that are different. Seeing a sequence of letters within a word, having a left-right concept, position-in-space concept and directionality concept, must be developed as well as a good visual memory . . . . Carefully related science experiences can be used effectively as an alternate approach for developing visual perceptual skills. (pp. 39-40)

Newman (1975) suggests another reason for why teachers "don't have time not to teach science." He observed that children who were initially unsuccessful in their achievement in reading and writing in regular language arts lessons continued to fail as they progressed through school. He found that science helped a variety of youngsters who were unsuccessful in regular programs achieve some success in school, thereby leading to higher motivation and higher achievement overall.

---

[5]The nature of the inter-relationships between the learning of science and language remains largely unknown. Efforts to understand how some of the same cognitive mechanisms involved in learning science operate on the learning of language are only beginning.

Not only is learning science for its own sake important, but it might play a significant role in upgrading the learning of language. One might also wonder whether science teachers can make some explicit efforts to use science experiences as a vehicle for upgrading language skills. Suggested activities may be found in the "List of Creative Writing Themes that Can Be Coordinated with Various Science Units" (Reid & McGlathery, 1977), and in experimental programs like "Integrating Science with the Creative Arts in Career Education" (Yae & Kelly, 1975). More research and development are needed to provide a basis for the systematic use of science in upgrading reading and writing.[6]

It should be noted that the claims we make about the value of science for the acquisition of reading and writing skills probably hold for other subject areas as well. A fascinating study by Crano (Note 18) and his co-workers illustrates this point. In the study, a group of poor-reading high school students was given experience in reading charts and graphs as part of a summer remedial program (which also included conventional reading improvement exercises). Their post-test scores were substantially higher than those of a control group, which spent more time, overall, doing more reading exercises. This finding may seem logical, but those who control the curriculum and accountability systems will not revise their programs until more research is carried out to explicate the complex relationships among such factors as time-on-task, fatigue, boredom, and specific inter-task transfer.

Another question worth investigating is to what extent educators can take advantage of the fact that the learning day is essentially the whole waking day -- not merely the five or six hours of the school day.

---

[6]An interesting question, one which warrants research, is whether we can improve language performance by increasing the use of essay tests in science (and other subject areas) to say, 50%. At present, there are high school graduates in the U.S. who have never taken a test other than multiple-choice.

There are some extraordinary resources within the community (such as television and museums) that may be more powerful tools for teaching science than anything we can come up with in our 40-minute laboratory periods in the schools. But as long as educators consider the walls of the schools the boundaries of science education, they will fail to take advantage of such possibilities for increasing the scientific literacy of the population.

Finally, one of the ways science and mathematics educators can win is by being willing to lose. Joseph Schwab (1974) argued that, for the sake of the future of science education, science educators ought to be prepared to give up half of their presently-allotted curriculum time and to contribute it to new integrated curricula that would cut across subject areas. He did not base his argument on the research literature on transfer or on the political reality that, whether science educators give the time up or not, they are going to lose it. He based it on the concept of curricular integration, a concept he and many other curriculum specialists have advocated for years, and one which must now be revived.

The Unified Science and Mathematics for Elementary Schools (USMES) program (whose support was suspended by NSF in 1976) represented precisely the kind of integrated science, mathematics, social studies curriculum that Schwab and others recommend. The USMES could have been, and may yet become, the prototype for integrated curricula; certainly, though, such a prototype would redound to the greater benefit of reading comprehension and all the other basic skills if implemented. Programs like USMES demand teacher preparation and in-service teacher education. USMES was suspended because it was not a proper curriculum, capable of standing alone as a package. In the words of the NSF critics, it was more a philosophy of teaching than a curriculum. Apparently, it required too much commitment and thinking from teachers to be judged a suitable curriculum.

If programs like USMES are allowed to die, then shortly, because of the conditions we have described in this paper, science and mathematics education as we know it may also die. Science and math will become activities limited to those elite students who master their objectives early, while the others are receiving most of the teacher's help on the basics. Unless those of us in research and development and teacher education take initiatives to foster curriculum integration and instructional collaboration, we will see science and mathematics teaching join life-adjustment and core curricula as poignant footnotes to the history of twentieth century education.

Reference Notes

1. Davis, R. Curricular implications for research on teaching mathematics. In Proceedings of the Research on Teaching Mathematics Conference, May 1-4, 1977 (Occasional Paper No. 3). East Lansing: Institute for Research on Teaching, Michigan State University, 1978.

2. Allen, L. A scheme for content analysis of curricula. Honolulu: Curriculum Research and Development Group, University of Hawaii, 1976.

3. Blum, A. A scheme for curriculum adaptation. Jerusalem: Hebrew University of Jerusalem, 1976.

4. Ben Peretz, M. The development of a system for the content analysis of curricula. Unpublished doctoral dissertation, Hebrew University, Jerusalem, 1977.

5. Kilpatrick, J., Private communication, 1977.

6. Smith, E. The study of science teachers' planning process. Unpublished manuscript, Science and Math Teaching Center, Michigan State University, 1977.

7. Shroyer, J. Strategies of mathematics instruction. East Lansing: Institute for Research on Teaching, Michigan State University. In progress.

8. Hegarty, E. A study of the microbiology laboratories in two Australian universities. Unpublished doctoral disseration, University of New South Wales, 1977.

9. Kyle, W.C. An analysis of instructor and student behaviors in introductory and advanced laboratories of five science disciplines at the university level. Unpublished master's thesis, University of Iowa, 197

10. Penick, J.E. What are your students really doing in the laboratory? Paper presented at the meeting of the National Association of Research in Science Teaching, Cincinnati, March 1977.

11. Shymansky, J.A. Systematic observations and good laboratory instruction. Paper presented at the meeting of the National Association of Research in Science Teaching, Cincinnati, March 1977.

12. Connelly, F.M., Feingold, M., & Walshtrom, M.W. Science enquiry and science instruction. Report to the Canada Council, 1974.

13. McIntosh, N.E.S. Private communciation, 1977.

14. Smith, E. An analysis of concepts in science. Working papers. East Lansing, Mi.: Science and Mathematics Teaching Center, Michigan State University, 1977.

15. McLeod, R. New models for inservice education for teachers: A new approach to university service to schools. Paper presented at the Science and Math Center Anniversary Conference, Michigan State University, May 1977.

16. Rosenshine, B., & Berliner, D. Personal communication, 1977.

17. Quinn, M.E., & Kessler, C. Language acquisition as a byproduct of science instruction. Paper presented at the meeting of the National Association of Research in Science Teaching, Cincinnati, March 1977.

18. Crano, William. Department of Psychology, Michigan State University, 1976.

References

Ayers, J.B., & Mason, G. Differential effects of science -- A process approach upon change in Metropolitan Readiness Test scores among kindergarten children. The Reading Teacher, 1969, 22, 435-439.

Bennett, N. Teaching styles and pupil progress. London: Open Books, 1976.

Ben Zvi, R., Hofstein, A., Samuel, D., & Kempa, R.F. The attitude of high school students to the use of filmed experiments in laboratory instruction. Journal of Chemical Education, 1976, 53, 712-14. (a)

Ben Zvi, R., Hofstein, A., Samuel, D., & Kempa, R.F. The effectiveness of filmed experiments in high school chemical education. Journal of Chemical Education, 1976, 53, 518-29. (b)

Bloom, B.S. Human characteristics and school learning. New York: McGraw-Hill, 1976.

Bridgham, R.G. Conceptions of science and learning science. School Review, 1969, 78, 25-40.

Bruner, J. The process of education. Cambridge, Mass.: Harvard University Press, 1960.

Bruner, J. The process of education revisited. Phi Delta Kappan, 1971.

Bruner, J.S., Goodnow, J.J., & Austin, G.A. A study of thinking. New York: John Wiley, 1956.

Chomsky, N. Syntactic structures. The Hague: Mouton, 1957.

Doyle, J.D., & Lunetta, V.N. Piaget in perspective. School Science and Mathematics, 1977, 78, 475-480.

Educational Development Center. TORQUE. EDC Newsletter, 1976, 8, 9.

Erlwanger, S. Case studies of children's conceptions of mathematics: Part I. Journal of Children's Mathematical Behavior, 1975, 1, 157-283.

Harnischfeger, A., & Wiley, D. The teaching-learning process in elementary schools: A synoptic view. Curriculum Inquiry, 1976, 6 (1) 5-43.

Herron, M.D. The nature of scientific enquiry. School Review, 1971, 79, 171-212.

Huff, P., & Languis, M. The effects of the use of activities of SAPA on the oral communication skills of disadvantaged kindergarten children. Journal of Research in Science Teaching, 1973, 10, 165-173.

Hunt, J.M. Intelligence and experience. New York: Ronald Press, 1961.

Kempa, R.F., & Ward, J.E. The effect of different modes of task orientation on observational attainment in practical chemistry. Journal of Research in Science Teaching, 1975, 12, 69-76.

Klausmeier, H.J. Educational experience and cognitive development. Educational Psychologist, 1977, 12, 179-197.

McGlathery, G.E. An assessment of science achievement of five and six-year-old students of contrasting socio-economic backgrounds. Austin, Texas: University of Texas at Austin. ERIC Document Reproductive Service No. ED 026 2711.

McGuire, C. Simulation technique in the teaching and testing of problem-solving skills. Journal of Research in Science Teaching, 1976, 13, 89-100.

Miller, G.A. The magic number 7 plus or minus 2: Some limits on our capacity for processing information. Psychological Review, 1956, 53, 81-97.

Miller, G.A., Galanter, E., & Pribram, K.H. Plans and structure of behavior. New York: Holt, Rinehart & Winston, 1960.

Newell, A., Shaw, J.C., & Simon, H.A. Elements of a theory of human problem solving. Psychological Review, 1958, 65, 151-166.

Newman, D.B. You don't have time not to teach science. Science and Children, 1975, 12, 29-31.

Nussbaum, J., & Novak, J.D. An assessment of children's concepts of the earth utilizing structured interviews. Science Education, 1976, 60, 535-550.

Passow, A.H. Secondary education reform: Retrospect and prospect. New York: Teachers College, Columbia University, 1976.

Reid, H.K., & McGlathery, G. Science and creative writing. Science and Children, 1977, 14, 19-20.

Renner, J.W., & Coulter, V.J. Science achievement is above expectations in Norman, Oklahoma. Science and Children, 1976, 13, 26-27.

Rowe, M.B. Science and soul: Some musings on fate control. New York: Teachers College, Columbia University, 1970.

Schwab, J.J. The teaching of science as enquiry. In J.J. Schwab and P.F. Brandwein (Eds.), The teaching of science. Cambridge, Mass.: Harvard University Press, 1962.

Schwab, J.J. Decision and choice: The coming duty of science teaching. Journal in Science Teaching. 1974, 11 (4), 1-23.

Shulman, L.S., & Keisler, E.R. Learning by discovery: A critical appraisal. Chicago: Rand-McNally, 1966.

Shulman, L.S., & Lanier, J.E. The Institute for Research on Teaching: An overview. Journal of Teacher Education, 1977, 28, (4)44-49.

Shulman, L.S., & Tamir, P. Research on teaching in the natural sciences. In R.M.W. Travers (Ed.), Second handbook of research on teaching. Chicago: Rand-McNally, 1973.

Tamir, P. The Israeli High School Biology Project -- A case of curriculum adaptation. Curriculum Theory Network, 1976, 5, 305-315.

Tamir, P. How are the laboratories used. Journal of Research in Science Teaching, 1977, 14, 311-16.

Thier, M. Utilizing science experiences for developing visual perception skills. Science and Children, 1976, 13, 39-40.

Yae, K.Y.B., & Kelly, E.A. Integrating science with the creative arts in career education. Science and Children, 1975, 13, 22-23.

PUBLICATIONS

of the

Institute for Research on Teaching
Michigan State University

as of

February 1, 1979

To order any of the following publications please send check, money order, or prepaid purchase order -- payable to Michigan State University -- to: IRT Publications, 252 Erickson, MSU, East Lansing, MI 48824. Publication prices include only the cost of production and mailing. Michigan residents should add a 4% state sales tax to all orders. The Institute for Research on Teaching is funded primarily by the National Institute of Education, United States Department of Health, Education, and Welfare.

Research Series

No. 1 The Inquiry Theory: An information-processing approach to clinical problem-solving research and application. J.F. Vinsonhaler, C.C. Wagner, & A.S. Elstein. 1978. $2.00

No. 2 Impact on what? The importance of content covered. A.C. Porter, W.H. Schmidt, R.E. Floden, & D.J. Freeman. 1978. $1.75

No. 3 Instructions for using the AJ 832 plotting software package as modified for the CDC 6500 computer. M. Carlyn. 1977. $1.75

No. 4 Training manual for the classification of the content of fourth-grade mathematics. W.H. Schmidt, A.C. Porter, R.E. Floden, & D.J. Freeman. 1978. $2.25

No. 5 Flexner, accreditation, and evaluation. R.E. Floden. 1978. $1.75

No. 6 Analogy and credentialling. R.E. Floden. 1978. $1.25

No. 7 Conceptions of reading: The Rep test. M. Johnston. 1978. $1.00

No. 8 Research and development needs for the advancement of teacher education. J.E. Lanier & R.E. Floden. 1978. $3.00

No. 9 On the conceptualization of clinical problem solving. C.C. Wagner & J.F. Vinsonhaler. 1978. $1.50

* No. 10 Applications of the inquiry theory to reading and learning disabilities. L. Patriarca, J. VanRoekel, & J.F. Vinsonhaler. 1979.

No. 11 Methods for discovering cues used by judges: Two working papers. C.M. Clark & R.J. Yinger. 1978. $1.00

No. 12 Research on teacher thinking. C.M. Clark & R.J. Yinger. 1978. $2.[illegible]

No. 13 Data analysis strategies for quasi-experimental studies where differential group and individual growth rates are assumed. S. Olejnik. 1978. $2.75

No. 14 CLIPIR Pilot Observational Study of Reading Diagnosticians, 1976. A. Lee & A. Weinshank. 1978. $2.00 (with complete data, $5.75)

No. 15 The Inquiry Theoretic approach to clinical problem-solving research and application: Basic Management Information System (BMIS) technical manual Vol. 1. J.F. Vinsonhaler, C.C. Wagner, A.S. Elstein, & L.S. Shulman. 1978. $4.50

No. 16 The user's manual for the Basic Management Information System: BMIS technical manual Vol. 2. C.C. Wagner, J.F. Vinsonhaler, A.S. Elstein, & L.S. Shulman. 1978. $17.00

No. 17 Teachers' conceptions of reading: The evolution of a research study. R. Barr & G.G. Duffy. 1978. $1.25

No. 18 A study of teacher planning: Description and model of preactive decision making. R.J. Yinger. 1978. $4.25

No. 19 Fieldwork as basis for theory building in research on teaching. R.J. Yinger. 1978. $2.25

No. 20 Choice of a model for research on teacher thinking. C.M. Clark. 1978. $1.50

No. 21 Conceptual issues in the content/strategy distinction. D.J. Freeman. 1978. $2.25

No. 22 An econometric perspective on classroom reading instruction. B.W. Brown & D.H. Saks. 1978. $1.75

No. 23 Identifying cues for use in studies of teacher judgment. C.M. Clark, R.J. Yinger, & S.C. Wildfong. 1978. $1.75

No. 24 Teacher autonomy and the control of content taught. A.C. Porter. 1978. $3.75

No. 25 Don't they all measure the same thing? Consequences of standardized test selection. R.E. Floden, A.C. Porter, W.H. Schmidt, & D.J. Freeman. 1978. $1.50

* No. 26 Critical moments in the teaching of mathematics. J.C. Shroyer. 1978.

No. 27 Characteristics of the clinical problem-solving model and its relevance to educational research. (Formerly available as an IRT collateral paper.) A.S. Elstein, L.S. Shulman, J.F. Vinsonhaler, C.C. Wagner, & L. Bader. 1978. $1.25

* No. 28 The consistency of reading diagnosis. A. Weinshank. 1978.

* No. 29 The Inquiry Theory research paradigm. C.C. Wagner. 1978.

* No. 30 Simulating the problem solving of reading clinicians. J.F. Vinsonhaler. 1978.

* No. 31 Training reading specialists in diagnosis. G. Sherman. 1978.

No. 32 Classroom management in the elementary grades. J.E. Brophy & J.C. Putnam. 1978. $3.25

No. 33 An ethnographic study of a teacher's classroom perspective: Implications for curriculum. V.J. Janesick. 1978. $2.25

No. 34 The problem of dead letters: Social perspectives on the teaching of writing. S. Florio. 1978. $1.50

No. 35 Measuring content of instruction. W.H. Schmidt. 1978. $1.50

* No. 36 The relationship of teacher alienation to school workplace characteristics and career stages of teachers. M.J. Vavrus. 1978. $2.50

No. 37 The relationship between diagnosis and remediation in reading: A pilot study. A. Weinshank. 1978. $1.75

* No. 38 Teacher judgment of children's reading preferences. T.E. Evans & J.L. Byers. 1979. $2.00

* No. 39 The teaching styles at South Bay School. B. Joyce. 1979. $2.25

* No. 40 Teachers' thoughts while teaching. B. Joyce. 1979. $2.25

* No. 41 Measuring teachers' conceptions about reading. G.G. Duffy & W. Metheny. 1979. $1.75

* No. 42 Studies of clinical problem-solving behavior in reading diagnosis. D. Gil, J.F. Vinsonhaler, & C.C. Wagner. 1979. $2.00

* No. 43 Study of the value/belief patterns of teachers and administrators. P. Cusick. 1979.

No. 44 Teacher perceptions of student affect. R.S. Prawat. 1979. $2.50

Occasional Papers

No. 1 Teachers' concerns and conceptions of reading and the teaching of reading: A literature review. G. Belli, G. Blom & A. Reiser. 1977. Limited number of free copies.

No. 2 Teachers and researchers: Toward a proper division of labor. C. Kennedy. 1977. Limited number of free copies.

No. 3 A causal analysis of attitudes toward leadership training in a classroom setting. J.E. Hunter, R.F. Hunter & J.E. Lopis. 1978. $2.00

* No. 4 The teacher as colleague in classroom research. S. Florio & M. Walsh. 1978.

No. 5 Form and function in mother-toddler conversational turn-taking. M.L. Donahue. 1978. $1.75

No. 6 Individual school buildings do account for differences in measured pupil performance. L.W. Lezotte & J. Passalacqua. 1978. $1.25

No. 7 Research on teaching: A dynamic area of inquiry. J.E. Lanier. 1978. $1.25

No. 8 Test design: A view from practice. L.S. Shulman. 1978. $1.75

No. 9 Relationships between testing and curriculum. A.C. Porter. 1978. $1.00

No. 10 Psychology and mathematics education revisited: 1976. L.S. Shulman. 1978. $1.75

No. 11 Science and mathematics education: Retrospect and prospect. L.S. Shulman & P. Tamir. 1978. $2.00

No. 12 Relating theory to practice in educational research: A working paper. L.S. Shulman. 1978. $1.75

No. 13 Classroom discipline: Toward a diagnostic model integrating teachers' thoughts and actions. D. Gil & P.S. Heller. 1978. $1.00

No. 14 Attention and modality effects in STM: A second look. T.Evans & J. Byers. 1978. $1.75

* No. 15 Mere ethnography: Some problems in its use in educational practice. F. Erickson. 1979. $2.00

* No. 16 On standards of descriptive validity in studies of classroom activity. F. Erickson. $2.00

* No. 17 Changes in school characteristics coincident with changes in student achievement. W.B. Brookover, & L.W. Lezotte. 1979. $5.00 (Executive Summary $1.00)

Conference Series

No. 1 Current directions in research on teaching: A meeting of the Invisible College of Researchers on Teaching, November 17-19, 1976. 1977. $4.25

No. 2 Report of a seminar on field research methods in education. P.A. Cusick. 1978. $1.50

No. 3 Proceedings of the Research-on-Teaching Mathematics Conference, May 1-4. 1977. 1978. $8.25

No. 4 Teachers attaining new roles in research: A challenge for the education community. L.D. Shalaway, J.E. Lanier et al. 1978. $3.50

---

*In productior and will be available by May 1979. Please write for exact price and publication date.